Shipboard Data Assimilation System/Doppler Radar

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LONG-TERM GOALS

Our goal is to develop a short-term high-resolution data assimilation capability that can provide the Navy with improved analyses and forecasts of atmospheric conditions with sufficient detail and accuracy for supporting the Navy mission in threat detection, weapons development, and weather safe operations. The data assimilation system will utilize all available weather data, such as Doppler radar, in situ, and remotely sensed observations. The system will run efficiently and generate a detailed analysis of the atmosphere with sufficient accuracy to predict Electro-Magnetic/Electro-Optical (EM/EO) propagation and target area weather conditions. This information can then be fed back to SPY-1 radar and other weapon system operators to improve detection capabilities.

OBJECTIVES

The objective of this research is to build a set of comprehensive data assimilation algorithms for the on-scene (OS) version of the Coupled Ocean/Atmospheric Mesoscale Prediction System (COAMPS®), and at the same time, investigate the impact of high-resolution data assimilation on short-term mesoscale numerical weather prediction. This data assimilation scheme will be able to analyze mesoscale weather by applying sophisticated analysis procedures capable of ingesting the information from Doppler radar, satellite, and other remote sensors. The primary focus of this effort will be to design a system that optimally utilizes the available weather data such as DoD Doppler radar data for initializing COAMPS-OS®.

APPROACH

The Naval Research Laboratory (NRL) and the University of Oklahoma (OU) are jointly developing a mesoscale variational data assimilation system (3.5dVar). This 3.5dVar system uses the background fields provided by atmospheric predictions from COAMPS at non-synoptic times and/or by analyses from the newly developed NRL Atmospheric Variational Data Assimilation System (NAVDAS) at synoptic times. Simplified adjoint methods are used to achieve the high computational efficiency needed to assimilate high-resolution data from Doppler radars (including DoD radars on ships and at forward-deployed locations). The analysis increment fields are expressed by B-spline basis functions to optimally filter noise while the analysis is performed directly on the COAMPS grid. The assimilation time window is synchronized with COAMPS integration time steps and radar volumetric scans to enhance the coupling of the model with the data. To compliment the radar assimilation

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14. ABSTRACT

Our goal is to develop a short-term high-resolution data assimilation capability that can provide the Navy with improved analyses and forecasts of atmospheric conditions with sufficient detail and accuracy for supporting the Navy mission in threat detection, weapons development, and weather safe operations. The data assimilation system will utilize all available weather data, such as Doppler radar, in situ, and remotely sensed observations. The system will run efficiently and generate a detailed analysis of the atmosphere with sufficient accuracy to predict Electro-Magnetic/Electro-Optical (EM/EO) propagation and target area weather conditions. This information can then be fed back to SPY-1 radar and other weapon system operators to improve detection capabilities.

15. SUBJECT TERMS

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system, a separate cloud analysis package was adapted for COAMPS from the OU Advanced Regional Prediction System (ARPS). The ARPS Data Analysis System (ADAS) is used to analyze high-resolution geostationary satellite observations (such as the GOES infrared and visible imagery), surface cloud observations, and reflectivity from radars. The ADAS cloud analysis provides estimates of cloud water and ice over a much larger region than is possible from using the 3.5dVar system with the radar data alone.

WORK COMPLETED

Research efforts for this project in the fiscal year 2005 have been continuously focused on studying the impact of wind and cloud data assimilation from Doppler radar and other remotely sensed data on mesoscale NWP model prediction. The hourly data assimilation procedure developed for NRL NOWCAST and On-Scene data assimilation has been used for this study. Cloud and precipitation mixing ratios retrieved by ADAS from satellite IR and vis channel data and radar reflectivity observations have been assimilated into COAMPS in a hourly-cycled mode together with the three-dimensional winds retrieved from radar observations of radial velocity using the 3.5dVar system. Studies have been conducted to investigate the impact of the assimilated data on model's very-short-term prediction of severe storms and other hazardous weather events. Contributions from each data assimilation component and the overall improvement in model prediction have been assessed. To quantify the impact of data assimilation on model forecasts, two verification systems have been developed to verify model forecasts against radar observations. The first one is the NRL 3-D Radar Mosaic System. By integrating volumetric scans of radar reflectivity from each of individual radars in a storm region into one three-dimensional reflectivity field on a Cartesian grid, this system provides ground truth data that are not available anywhere else for the validation of model forecasts of the three-dimensional hydrometeor fields (cloud liquid water, cloud ice water, rain, snow, and graupel) with a nearly complete coverage of large storm systems (for example, a hurricane). In addition to model verification, this system can also be used for storm studies and radar data assimilation. The second verification system is the NRL three-dimensional radar wind analysis system. This system calculates radar radial velocities from model forecasts of three-dimensional winds (u, v, w) at radar observational grid points and then compares the calculated radial velocities with radar observations. Statistics are computed during the verification. This is the first system capable of verifying three-dimensional wind forecasts with the ability of showing model forecast errors both in phase and in magnitude. It has showed its usefulness in mesoscale model verification.

Efforts also continue for radar data processing and quality control (QC). Software has been developed and implemented to ingest and display Doppler radar data stored in Universal Format (UF). This paves the way to use DoD radar data for NOWCAST and data assimilation. A comprehensive radar data quality control suite is under development that will merge the National Center for Atmospheric Research (NCAR) Radar Echo Classifier (REC) algorithm, the MIT/Lincoln Laboratory Data Quality Assurance system, the National Severe Storms Laboratory (NSSL) radar data quality control system with the algorithms developed at NRL Monterey to provide a complete radar quality control for the radial velocity and reflectivity data from the WSR-88D radars, the Supplemental Weather Radar (SWR), the SPS-48 air control radar, and other DoD radars. This will further improve the radar data quality in the data assimilation and consequently the impact on model prediction.

RESULTS

The data assimilation system has been extensively tested with case studies. To fully examine the contribution from each data assimilation component and the overall effect, five experiments were conducted as shown in Table 1. Figure 1 illustrates the procedures in which data assimilation was cycled to assimilate the retrieved wind, thermodynamic, cloud, and precipitation fields into COAMPS every hour during the data assimilation period. After the final data assimilation cycle, a 14-hour forecast was executed.

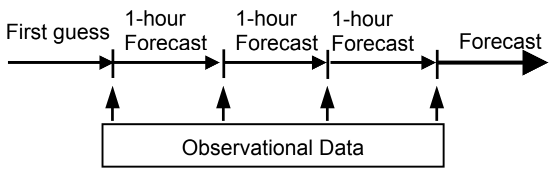

Fig. 1. Illustration of data assimilation procedures

Table 1. Data assimilation experiments

CNTL	No data assimilation
CLD	Satellite IR and vis data
CLD+PR	Satellite IR and vis data, radar reflectivity
WIND	Radar radial velocity
ALL	All data above

To study the impact of the data assimilation on model forecasts, root-mean-square (RMS) differences of model forecasts between each of data assimilation experiment and the control run were calculated as a function of forecast time. Figure 2 gives the results for the fields of u-wind component (u), temperature (T), water vapor mixing ratio (q_v), and rain water mixing ratio (q_r). It is obvious that all model forecasts responded significantly to the data assimilation in all data assimilation experiments. It is also interesting to note that the data assimilation impacts stayed in the model forecasts for the whole forecast period except the rain water mixing ratio, in which the data assimilation impact disappeared right after the storm system moved away from the model domain.

The system developed for verifying model wind forecasts against radar observations of radial velocity was used to assess the values of radar and satellite data added to the model wind forecasts. This system calculates the model-predicted radial velocities, at radar observational grids, from model three-dimensional wind forecasts (u, v, w) and then compares the calculated radial velocities with radar observations. Statistics of RMS errors and correlation coefficients are computed for each radar scan elevation. Figure 3 shows the calculated correlation coefficients and RMS errors for the first hour wind forecasts from all experiments as a function of radar scan elevations while Fig. 4 gives the time variations of the RMS errors and coefficients from one particular radar elevation scan. The improvements in model wind forecasts by all the data assimilation experiments can be seen clearly in Figs. 3 and 4, with the biggest improvement from the combined data assimilation at the first forecast hour and from the radial velocity assimilation experiment for rest of the forecast time. Accompanying the wind improvement, our results (not shown) also indicated notable improvements in storm location and intensity prediction.

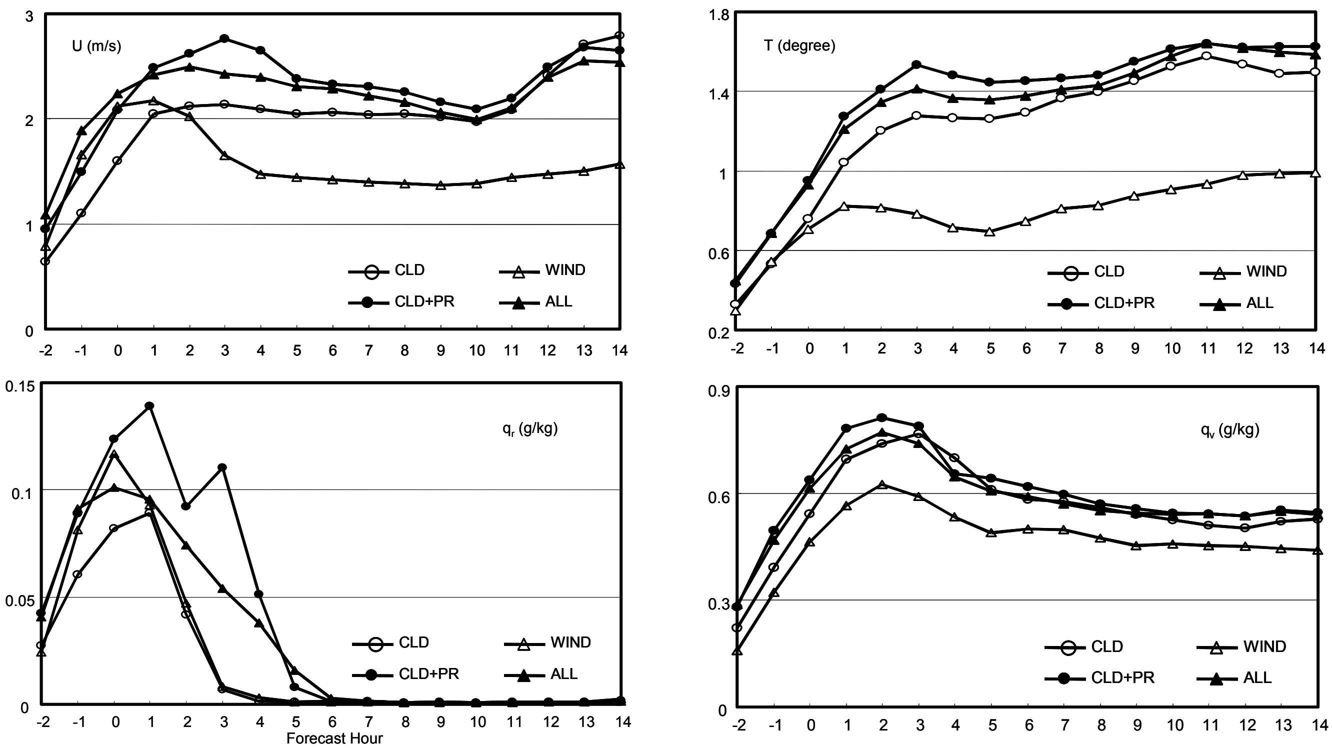

Fig. 2 Root-mean-square differences of model forecasts between the data assimilation experiments and the control run.

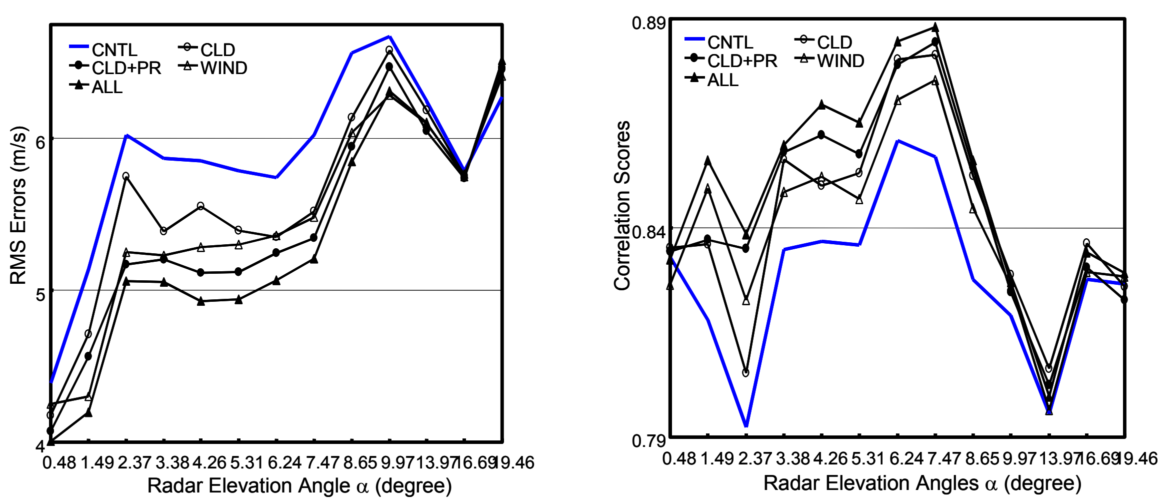

Fig. 3 Root-mean-square errors and correlation coefficients of radial velocities calculated from model 1-hour forecasts of three-dimensional winds verified against radar

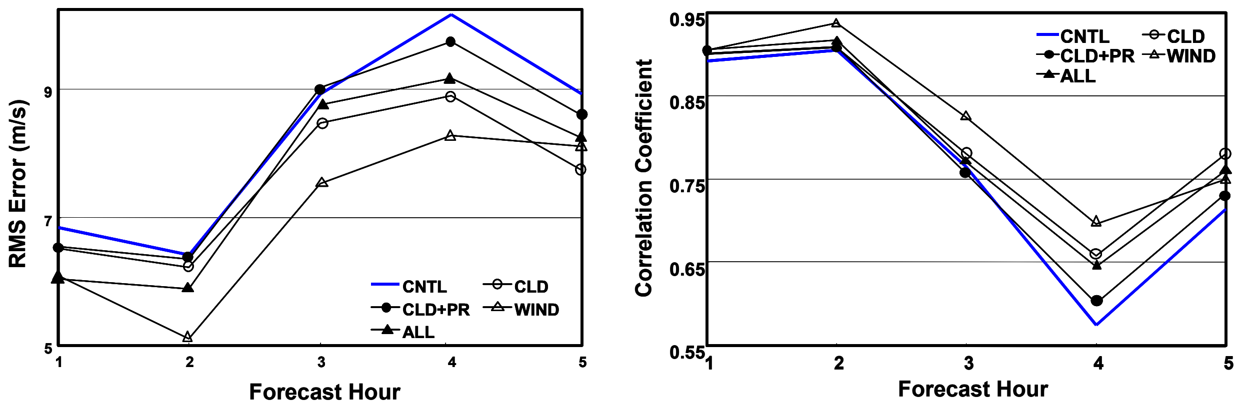

Fig. 4 Time variation of root-mean-square errors and correlation coefficients of radial velocities calculated from model forecasts of three-dimensional winds verified against radar observations at elevation angle of 2.37 degree.

IMPACT/APPLICATIONS

The ADAS cloud analysis and the 3.5dVar wind analysis systems that use geostationary satellite data, surface observations and radar measurements running in real-time with the COAMPS-OS will provide the Navy, through the NRL NOWCAST system, with near real-time, three-dimensional cloud and wind analyses in any region of interest to support the Navy's mission. The technology was demonstrated during Fleet Battle Experiment – Juliet with products providing up-to-date, detailed information to tactical decision makers about the three-dimensional atmospheric battlespace conditions. This information is simultaneously assimilated into the high-resolution COAMPS model to improve short-term theater-scale weather prediction. The high-resolution winds from both the data assimilation system and the COAMPS model forecast are also used to drive chemical/biological (CB) dispersion models, which are used for assessing contamination avoidance and decontamination strategies. While focusing on battlespace environmental applications, this work also establishes a scientific framework for utilizing radar-derived meteorological information in nowcasting and numerical weather prediction applications.

TRANSITIONS

The ADAS cloud analysis and cloud verification system has been successfully transited to COAMPS-OS 1.3 in 6.4 programs (PE 0603207N). The ADAS cloud verification algorithms and associated source codes have also been adapted by COAMPS Verification System for cloud forecast verification. The 3.5dVar Radar Wind Analysis System is being implemented to run real-time for NOWCAST at the Naval Strike and Air Warfare Center at Fallon, Nevada. The NRL 3D Radar Mosaic system originally developed for radar data assimilation is also transitioned to NRL NOWCAST for processing real-time radar data for TITAN (a storm nowcasting system).

PATENTS

Three-Dimensional Radar Reflectivity Mosaic System.

RELATED PROJECTS

Related NRL base projects include BE-235-001, Optimum Use of DoD Radar Data in Battlespace Environmental Prediction and BE 35-2-19, Data Assimilation for Mesoscale Prediction. Other related projects at NRL include Nowcast for the Next Generation Navy (ONR, N0001405WX20413), On-Scene Tactical Atmospheric Forecast Capability supported by the Oceanographer of the Navy (N61, PE 63207N x2342), and Real-Time Meteorological Battlespace Characterization in Support of Sea Power 21 (ONR, N0001405WX20414).

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